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Cambrian rocks of East Point, Nahant Massachusetts

Bailey, Richard H.

CAMBRIAN ROCKS OF EAST POINT, NAHANT, MASSACHUSETTS

Richard H. Bailey
Department of Earth Sciences
Northeastern University
Boston, MA 02115

Introduction

The quintessential stratigraphic component of Avalonian terranes of eastern North America is a Cambrian succession bearing the so-called Acado-Baltic trilobite assemblage. Spectacular sea cliffs at East Point, the easternmost extremity of Nahant, Massachusetts, afford an opportunity to examine a continuous and well exposed Lower Cambrian section on the Boston Platform. The Nahant Gabbro, sills, abundant dikes, and faults cut the Cambrian strata and add to the geological excitement. Indeed, it is difficult to move more than a few meters along the cliffs without discovering a feature that will arouse your curiosity. This is also a wonderful place to watch waves crash against cliffs and to stare across the Atlantic in the direction of Africa.

Regional Lower Cambrian Stratigraphy

Cambrian rocks of Nahant are correlated with distinctive green and red nodular slates of the Weymouth Formation (LaForge, 1932) exposed in the Mill Cove area of Weymouth (Figure 1). Trilobites have never been found in Nahant Strata (a slate pebble with *Strenuella* was found; Grabau, 1900), but a thin zone in the Weymouth Formation at the type locality (Burr, 1900; Grabau, 1900) yielded a diagnostic trilobite assemblage (*Strenuella*, *Callavia*, and *Weymouthia*) indicative of the late Early Cambrian of the Acado-Baltic faunal province and similar horizons in England and Morocco (Shaw, 1950; Theokritoff, 1968; Anstey, 1979). The Hoppin Formation at Hoppin Hill near North Attleboro, (Figure 1) also contains *Strenuella strenua* (Billings). A number of workers have noted (Foerste, *in* Shaler and others, 1899; Grabau 1900; Theokritoff, 1968; Landing and Brett, 1982) that in both the Hoppin and Weymouth Formations the trilobite bearing assemblages overlie or are separated from a fauna dominated by small conoidal fossils. Landing and Brett (1982) assigned the lower part of the Hoppin Formation, and the limestones of the Weymouth Formation at Nahant which lack trilobites, to the earliest Cambrian Tommotian Stage (Figure 1) and the microfauna associated with the *Strenuella* (trilobite) bearing beds at Hoppin Hill to the overlying Atdabanian Stage. The restriction of faunas to particular lithofacies, the very limited exposure of good stratigraphic sections, the intimate association of the trilobite and non-trilobite assemblages, and the occurrence of a trilobite(?) in limestone at Nahant suggest to me that the

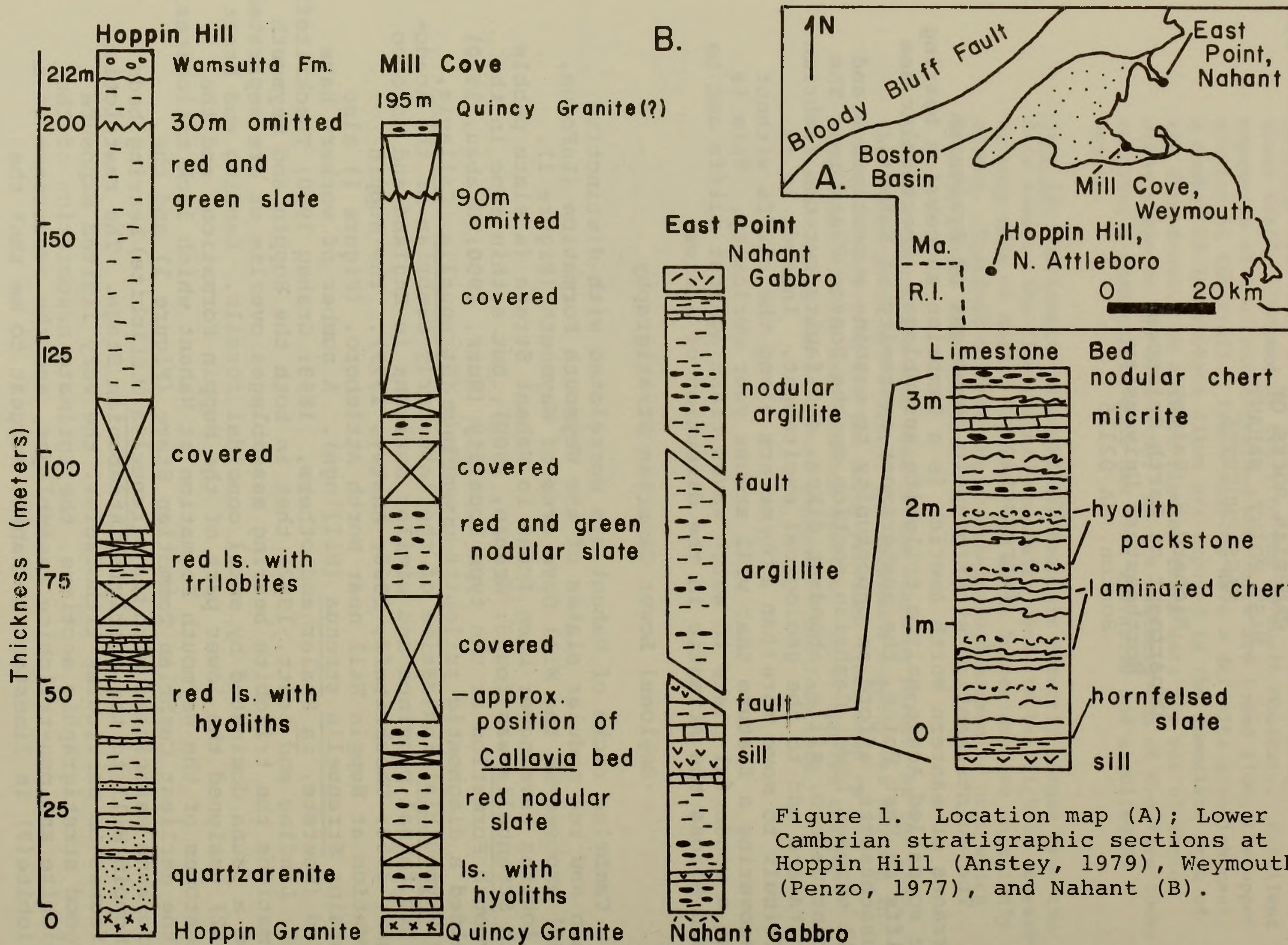


Figure 1. Location map (A); Lower Cambrian stratigraphic sections at Hoppin Hill (Anstey, 1979), Weymouth (Penzo, 1977), and Nahant (B).

Lower Cambrian rocks of eastern Massachusetts are probably not Tommotian but lower Atdabanian or slightly younger. Theokritoff (1968) explained the lack of co-occurrence of the trilobite and non-trilobite faunas as a probable result of facies control of assemblages and he therefore suggested that a non-trilobite Coleoloides fauna need not necessarily be earliest Cambrian. Landing, Nowland, and Fletcher (1980) also report the extension of several typical Tommotian phosphatic microfossil ranges well into the Callavia zone in Nova Scotia. We clearly need a better understanding of the taxonomy, stratigraphic ranges, and paleocecology of many of the non-trilobite index fossils of the earliest Cambrian. Until such knowledge is gained I suggest that application of the stage names of the Siberian Platform (Matthews and Missarzhevsky, 1975; Raaben, 1981) to the Cambrian successions of isolated areas such as eastern Massachusetts may be somewhat premature.

Strata equivalent in tectonic setting, depositional environment, and fossil content to the Hoppin and Weymouth Formations are excellently exposed in eastern Newfoundland and in more limited exposures in Nova Scotia and New Brunswick (McCartney, 1969). In Newfoundland and New Brunswick there is a profound, often angular, unconformity, with an overlying basal quartzarenite, as at Hoppin Hill, followed by the Lower Cambrian succession (Skehan, 1969). Kaye and Zartman (1980) have recently proposed that the Cambridge Formation of the late Precambrian Boston Basin grades upward into the Weymouth Formation to form a continuous and conformable succession. The lithologies of the Weymouth and the Cambridge are quite distinct and different, especially when viewed on the outcrop scale. The well documented nonconformity at the base of the Cambrian at Hoppin Hill (Billings, 1929; Dowse, 1950), less than 40 km to the southwest of the Boston Basin, is the result of transgression of shallow water facies onto a stable continental(?) block. The shallow water facies of the Weymouth and Hoppin Formations, the uncomformable association with stable basement, and the regional correlations do not support a basinal setting for the Weymouth Formation. Billings (1982) argues, on structural grounds, that an uncomplicated transition between the Boston Bay Group and the Cambrian strata in Weymouth and Quincy is unlikely.

Nahant Stratigraphy

About 130 m of strata are exposed in northerly dipping beds of East Point. It is difficult to present a simple stratigraphic section as there are numerous fault offsets and 2 thick sills that interrupt the sequence. The section consists of a dark silicified mudstone or argillite with interbedded nodular horizons and limestone beds. A 3m thick limestone bed is found on the southeast side of the point along the top of the cliff. The three basic Cambrian lithologies are discussed below.

Argillite

Most of the section is a brittle, dark gray to black, thinly laminated argillite. Bedding is faintly visible in hand specimen. Quartz silt and very fine quartz grains are present as thin, parallel laminae, and lenses (0.1-0.5 mm thick) or as scattered isolated grains. These laminae are separated by a dark structureless mudstone. Some undulating contacts resemble scour surfaces. Very rare burrow-like structures are present.

Nodular Argillite

The most characteristic lithology of the Weymouth is a red, green, or black slate or argillite containing elongate carbonate nodules. The nodules are from 0.5 to 3 cm in thickness and most are about 3 to 15 cm in length. They occur with varying frequency along bedding planes and occasionally are so abundant as to comprise a thin "limestone" bed. The nodules have been altered primarily by silicification, and by replacement with Ca-garnet, tremolite, wollastonite, and epidote. The highly altered nodules are often zoned or banded with chert and carbonate interiors and garnet and Ca-silicate rims (Bingham, 1977). Chertification initiated in the nodule often extended into the surrounding mudstone. I have seen no fossils in either the replaced or the relatively unaltered nodules. Underlying and overlying laminations in the mudstone are often deflected and appear to be displaced by nodules suggesting that the mudstone was unconsolidated when the nodules formed. The shapes of nodules are reminiscent of algal structures, but no definitive internal structure is present.

Limestone

White to light gray limestone beds range in thickness from 3 cm to 3 m. The very thin limestones usually occur in groups with interbedded, abundantly nodular, slate or argillite. Thicker limestones contain 0.5-3 cm thick, very thinly laminated, highly irregular, brownish or greenish chert beds. The cherts themselves do not contain fossils; however, patches of fossiliferous chertified limestones are associated with the greenish layers. Fossils occur in clearly defined thin zones within the limestones. These fossiliferous layers may be continous and traceable for several meters along the surface of the outcrops or they may be isolated as irregular masses.

Petrography of Limestones

The primary textures of limestones at East Point are remarkably well preserved given the proximity of igneous rocks. The rocks were originally biomicrites or fossil wackestones. The micrite has generally recrystallized to very finely crystalline sparry calcite although some patches of microspar are present (Figure 2). Abundant bioclast, primarily hyolithids, are composed

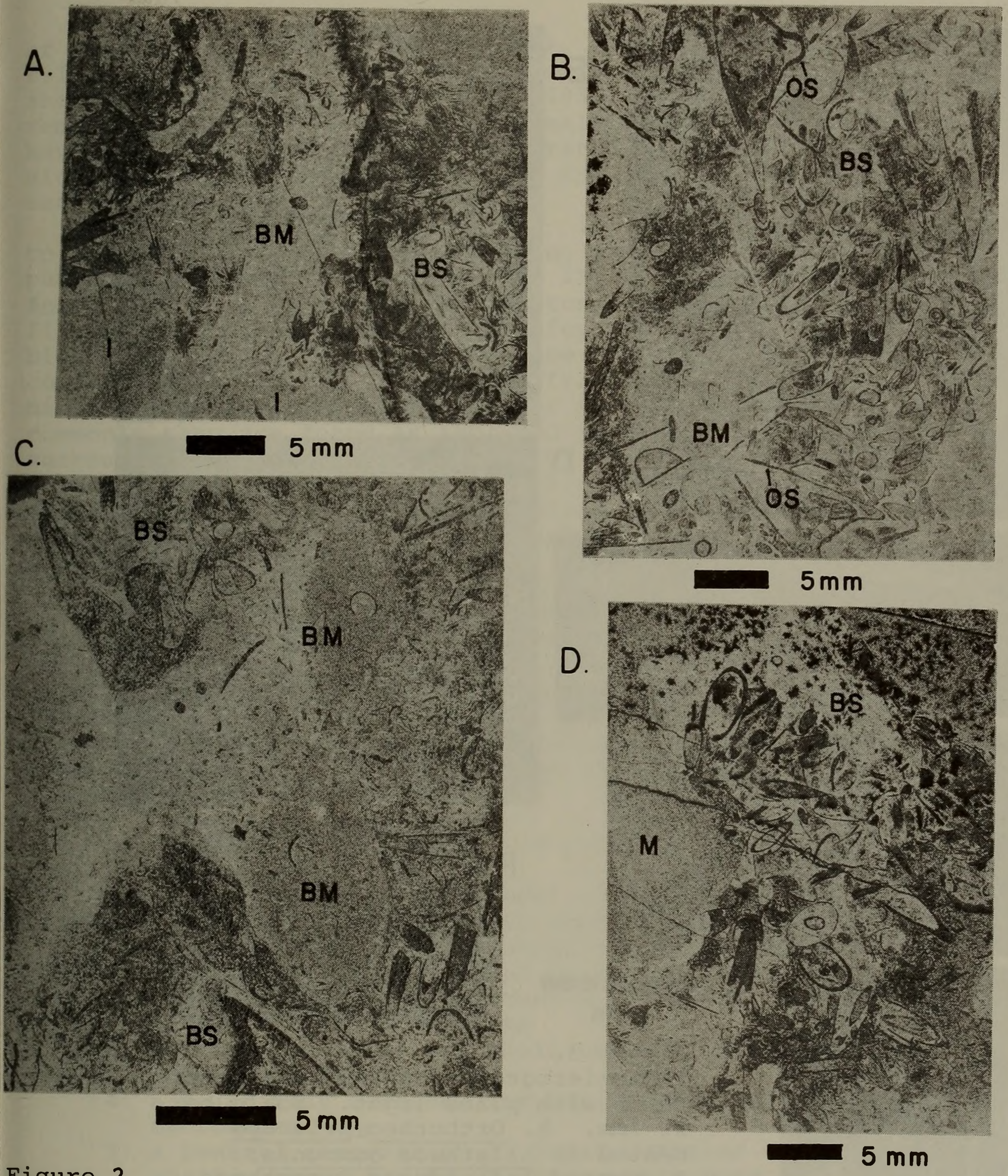


Figure 2
Negative prints of acetate peels from slabs cut parallel to bedding. Microfacies labeled micrite (M), biomicrite (BM), biosparite or packstone (BS), scale bar is 2 cm. A. intraclasts (I) surrounded by biomicrite and biosparite.; B. hyolith packstone and biosparite, note oblique sections of <u>Orthotheca searsi</u> (OS); C. irregular biomicrite mass surrounded by hyolith packstone; D. pocket of hyolith packstone, surrounded by micrite.

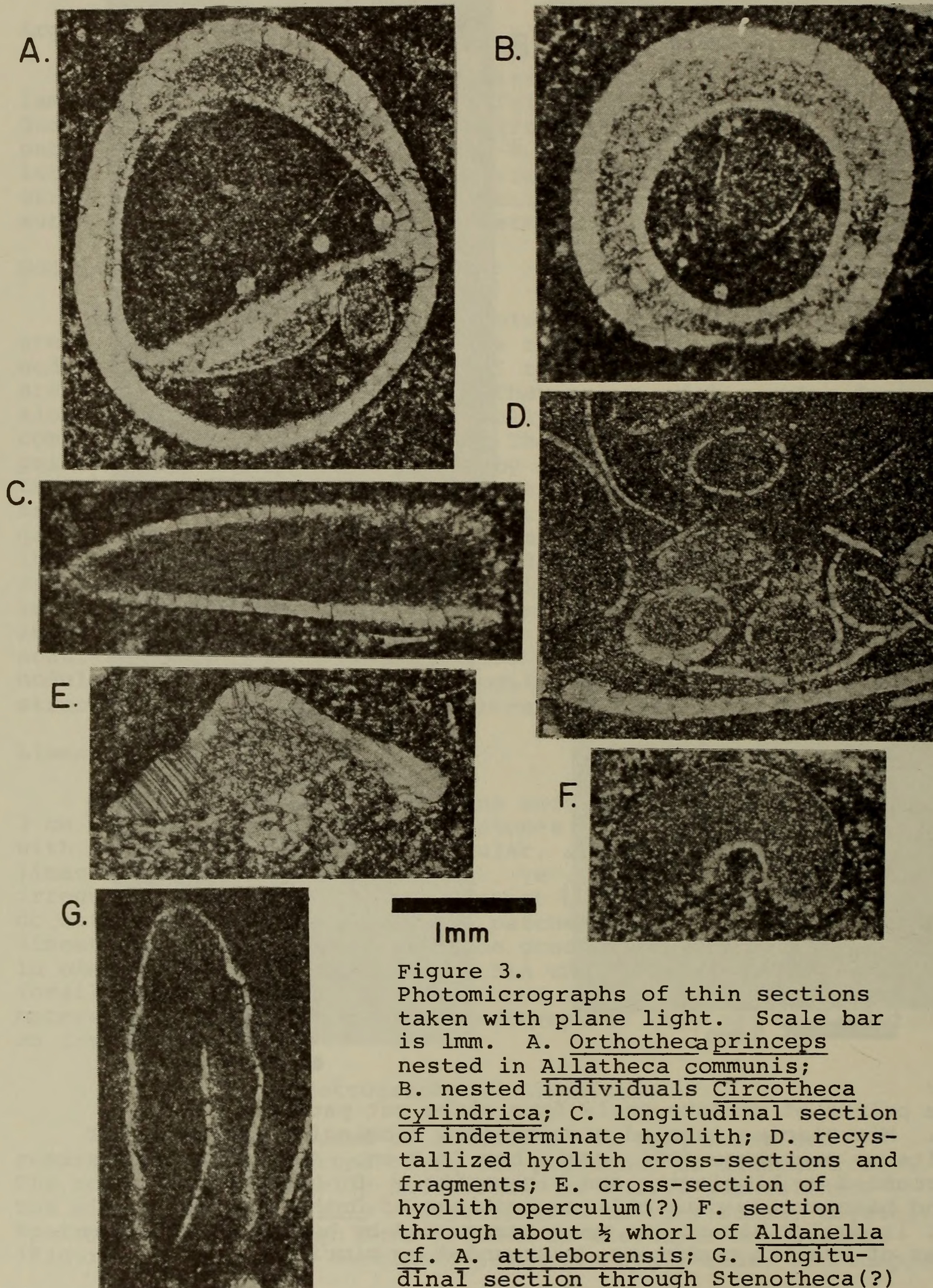


Figure 3.
Photomicrographs of thin sections taken with plane light. Scale bar is 1mm. A. Orthotheca princeps nested in Allatheca communis; B. nested individuals Circotheca cylindrica; C. longitudinal section of indeterminate hyolith; D. recystallized hyolith cross-sections and fragments; E. cross-section of hyolith operculum(?) F. section through about ½ whorl of Aldanella cf. A. attleborensis; G. longitudinal section through Stenotheca(?)

of blocky sparry calcite (Figure 3). This blocky spar may have filled voids created by the dissolution of original aragonitic shell material (James and Klappa, 1983). Although there are some remaining void-lining, finely crystalline, prismatic crystals most have been recrystallized or obliterated by recrystallization of micrite matrix. Common stylolites can be identified in thin section by truncation of fossils.

Three microfacies are present: 1) very sparsely fossiliferous to unfossiliferous micrite occurring in thin beds, irregular patches, or as intraclasts (Figure 2); 2) sparsely to moderately fossiliferous biomicrite or wackestone as thin beds or burrow (?) fillings that grade into unfossiliferous micrite or; 3) hyolith-biosparite, grainstone, or packstone. The latter microfacies is composed of abundant hyoliths and fragments. Some of these thin biosparite laminae overlie irregular scour(?) surfaces but more commonly they are found as isolated pockets or nests of fossils surrounded by micrite intraclasts or biomicrite. The inter-relationships of microfacies are illustrated in acetate peels of polished slabs cut parallel to bedding (Figure 2). Irregular masses of chert and epidote have secondarily altered areas of biomicrite and micrite.

Tubular and conoidal fossils do not show a strong preferred orientation. Long axis orientations (Figure 5) suggest only weak current sorting. Nested, or cone in cone hyolith specimens are fairly abundant and, along with the considerable abundance of fossil fragments indicate moderate post-mortem movement by currents. Long axes of many specimens of hyoliths are steeply inclined to bedding suggesting that the bottom may have been somewhat hummocky or irregular.

Environment of Deposition

A shallow subtidal environment is inferred for limestone strata at Nahant. Evidence supporting this conclusion is:

1) irregular laminae of biosparite and biomicrite with fragmental disarticulated shelly fossils
2) possible intraclasts around and between which accumulated biosparite and biomicrite
3) possible laminate and small domal or digitate stromatolites (now chertified)
4) a relatively diverse (for Early Cambrian) calcareous macrofauna.
5) a general association of Lower Cambrian hyoliths with shallow water facies in areas where more complete stratigraphy allows a confident asessment of paleo-environment. (especially Hoppin Hill and equivalent strata in Newfoundland).

This environment was interrupted by short term fluctuations in energy level, possibly storms, to produce the bioclastic rich layers mixed with intraclasts. Micrite accumulated during quiescent periods and during these periods stromatolites probably covered portions of the bottom. Limestone deposition ceased when the influx of fine clastics, possibly associated with concomitant deepening of the platform halted biogenic carbonate production. The thin nodular horizons result from a near balance between carbonate and clastic deposition. At no time during the deposition of the Nahant strata did a substantially uplifted extrabasinal source exist. Quartz silt is the coarsest extrabasinal material present. A stable platformal setting is further indicated by basal quartzarenite over granitic basement at Hoppin Hill and by quartzarenites in proximity to, but not in actual depositional contact with, the Weymouth Formation east of Mill Cove (Billings, 1982).

Paleontology

Foerste (1889) was the first to describe hyoliths from the Cambrian strata of Nahant. Louis Agassiz in 1850 and Sears in 1887 had also noted the presence of fossils in Nahant limestones (Grabau, 1900). By 1900 a well documented Lower Cambrian fauna was known from Hoppin Hill, Weymouth, Nahant, and from glacial cobbles and boulders at several localities. These Early Cambrian fossils are of great interest because they include some of the first shelled organisms to appear on earth. My paleontological studies, and those of my students, utilize thin sections, acetate peels, acid etched blocks, and specimens obtained by dissolving blocks. The discussion below lists and briefly describes taxa that have been found or reported from the limestone beds at Nahant.

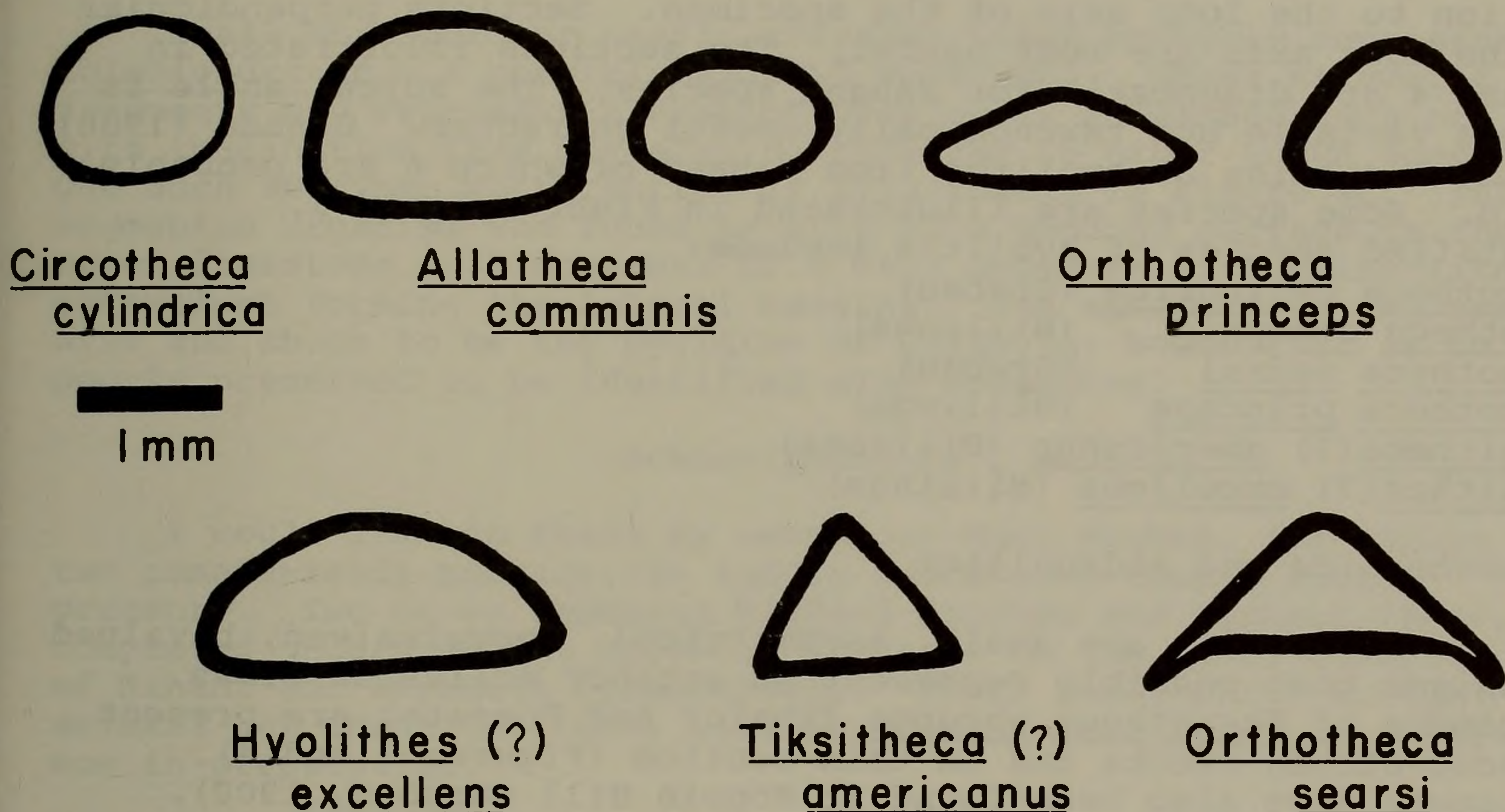
Brachiopods

Grabau (1900) illustrated two species of inarticulate brachiopods, Obolella cf. O. atlantica and Paterina bella. I have found several internal molds and cross-sections indicative of the former species, but the material is of poor quality. Obolella atlantica occurs with the trilobite Strenuella at both Hoppin Hill and Weymouth.

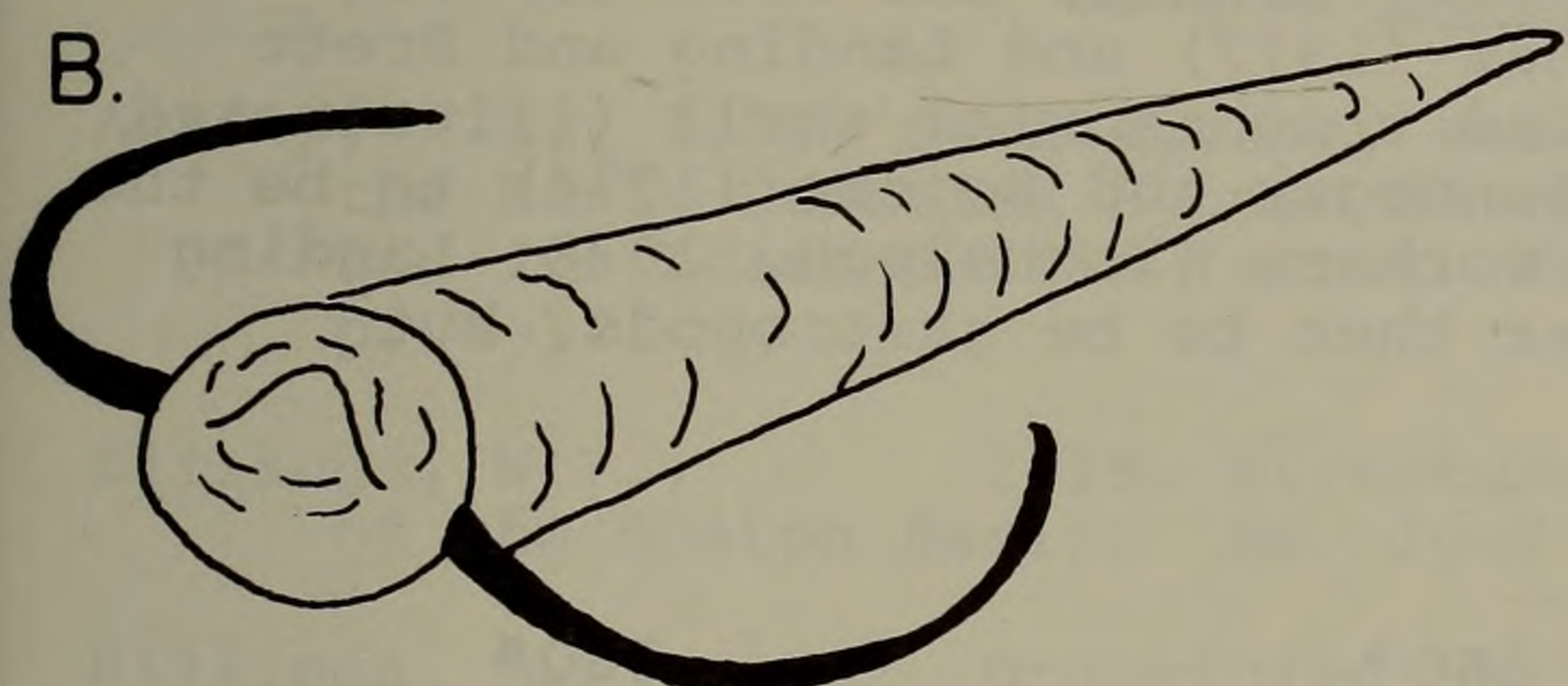
Hyoliths

The Nahant fauna is dominated by bilaterally symmetrical, conical fossils known as hyoliths. The taxonomic status of hyoliths is uncertain, with some workers (Runnegar and Pojeta, 1974) regarding them as an extinct phylum, and some (Marek and Yochelson, 1976; Yochelson, 1978) placing them as an extinct class in the mollusca. A typical hyolith skeleton is a straight or slightly curved, rounded, flattened, or triangular cone closed by an operculum. Two curved calcareous "whiskers"or appendages extending from the aperture (Yochelson, 1974) may have assisted in locomotion and or feeding (Figure 4). These creatures were probably benthic detritus feeders (Marek and Yochelson, 1976). Much of the detailed systematic work on hyoliths, particularly those from the Lower Cambrian, is based on specimens from the well exposed strata of the Siberian Platform (Raaben, 1981; Matthews and Missarzhevsky, 1975). The taxonomic assignment of sectioned hyoliths to genera

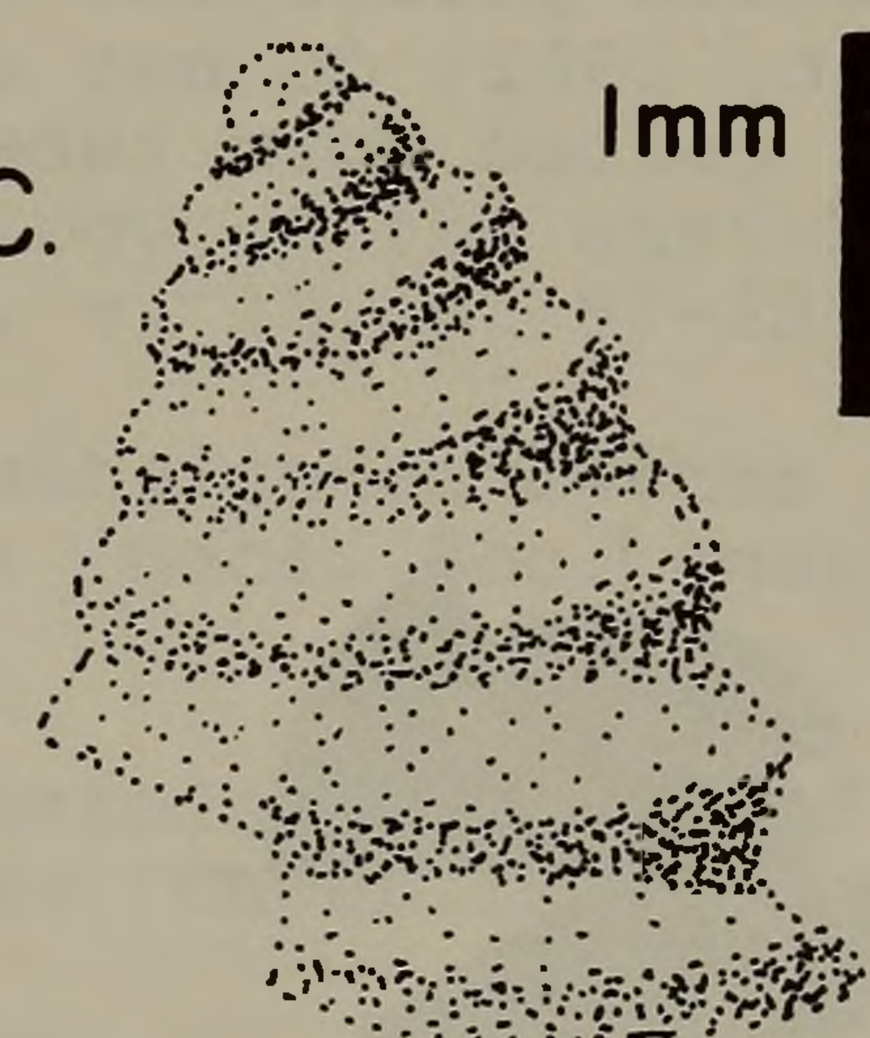
A.



B.



C.



D.

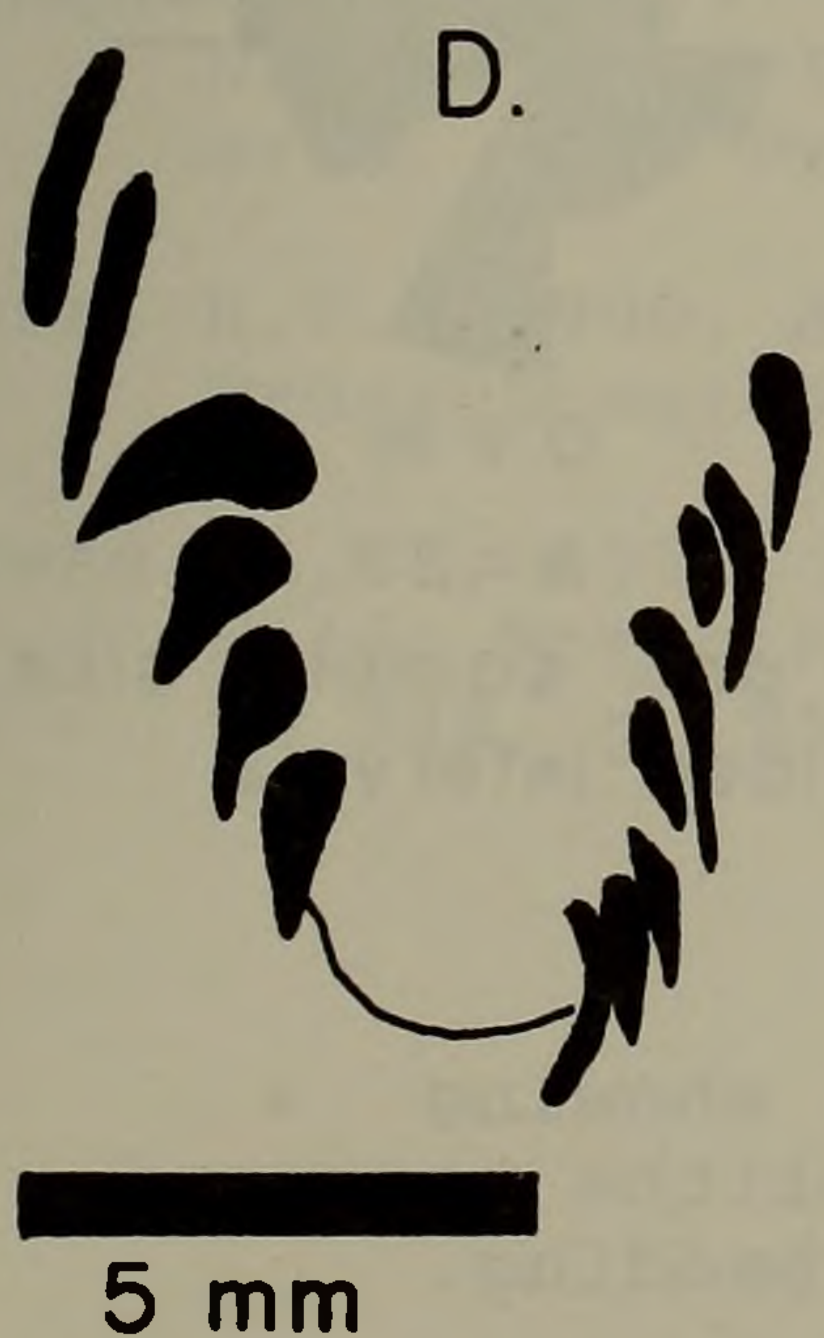


Figure 4
Sketches of Nahant fossils A. cross-sections of hyolith genera; B. reconstruction of living hyolith (from Yochelson, 1974); C. Stenotheca abrupta (after Sears, 1905, Fig. 209) D. camera-lucida sketch of trilobite pygidium(?).

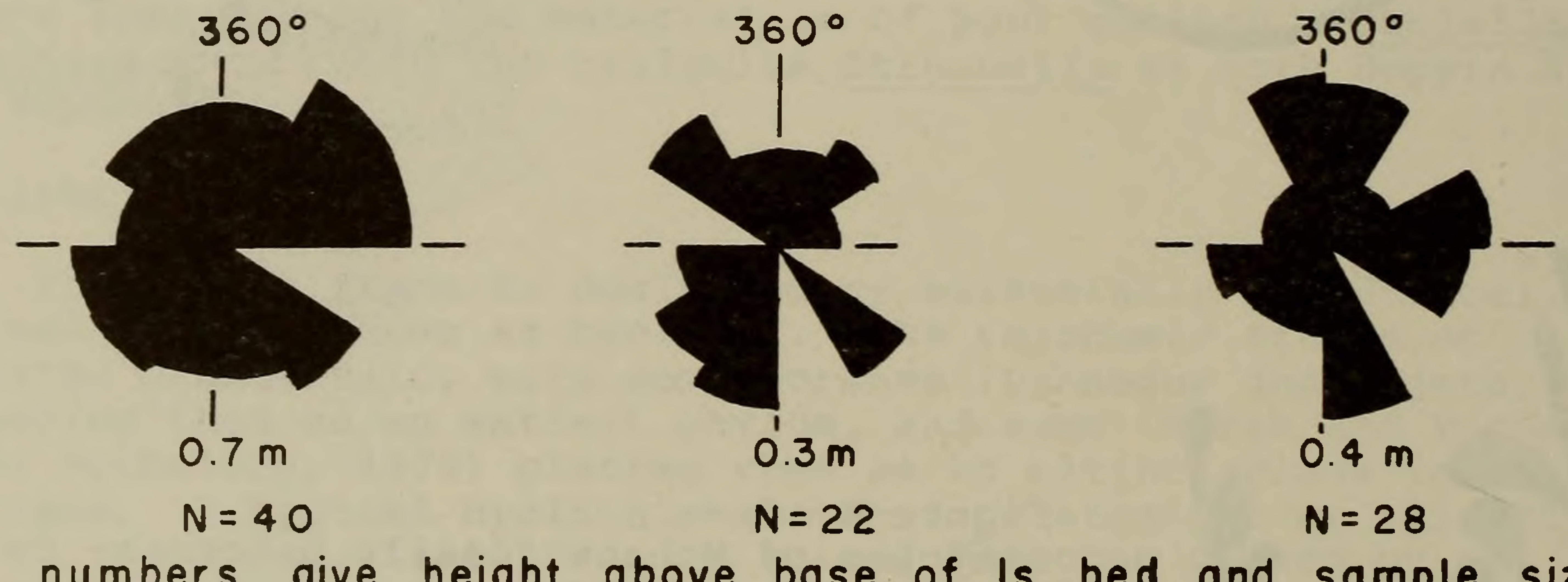
and especially to species can be very difficult as one must constantly consider the geometric effect of obliquity of the section to the long axis of the specimen. Sections perpendicular to the long axis are most useful. The sections illustrated in Figure 4 are diagnostic for Nahant species. The apical angle is also a variable but taxonomically useful character. Grabau (1900) listed 8 species of hyoliths from Nahant of which 6 are probably valid. Some species are illustrated in Figures 2 and 3. Identified species of hyoliths include:

<u>Circotheca cylindrica</u> (Grabau)
<u>Allatheca communis</u> (Billings)
<u>Orthotheca searsi</u> (Grabau)
<u>Orthotheca princeps</u> (Billings)
<u>Tiksitheca</u>(?) <u>americanus</u> (Billings)
<u>Hyolithes</u>(?) <u>excellens</u> (Billings)

Stenothecoids and Aldanellids

Stenothecoids are small, asymmetrical, inequivalved, bivalved organisms that possibly represent an extinct molluscan class. Specimens of <u>Stenotheca abrupta</u> (Shaler and Foerste) are present on acid-etched blocks and in thin section (Figures 3 and 4). Specimens have also been found at Hoppin Hill (Grabau, 1900).

<u>Aldanella</u> <u>cf.</u> <u>A.</u> <u>attleborensis</u> (Shaler and Foerste) was found in Nahant strata by Bingham (1977) and Landing and Brett (1982). This tiny, loosely coiled trochisprial shell (illustrated in Figure 3) is considered by Runnegar and Pojeta (1974) to be the oldest known gastropod. Other workers (Yochelson, 1978; Landing and Brett, 1982) do not consider them to be gastropods, but possibly coiled worm tubes.



numbers give height above base of ls. bed and sample size
non-conoidal fossils plotted in both opposite class intervals

Figure 5. Circular histograms (equal area) showing orientations of long axes of hyoliths measured in slabs and peels parallel to bedding.

Miscellaneous Specimens

Small straight or nearly straight tubes probably represent *Coleoloides* sp., a possible annelid worm tube. Other enigmatic fragments may represent pieces of previously mentioned taxa or with imagination they may also be referred to other known species. One such specimen worth noting is illustrated in Figure 4C. This segmented organism was found *in situ* on a bedding surface in the upper limestone. It consists of 6 or 7 segments with spine-like extensions forming the lateral margins. The specimen is the proper size and shape to be the pygidium of *Callavia*; however it is to poorly preserved to be identified with certainty.

Acknowledgments

I would like to thank my secretary Mary Meehan, for typing two camera-ready manuscripts for me under more than a little pressure. Two of my students, Michael Bingham and Michael Penzo, completed undergraduate research projects on the Lower Cambrian of Nahant and Weymouth respectively. Their work, which brought several new ideas to light, will be covered more fully in a paper now in preparation.

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Road Log

Mileage	
0.0	Inn at Danvers Parking lot.
0.05	Exit onto Dayton St. on north side of Inn; 180° right on Dayton onto Armory Rd.
0.1	Left at sign for "Boston-Newburyport Rt. 95"
0.2	Right at intersection; follow sign for Rts. 95 and 1 Boston and Topsfield"
0.3	Left at intersection; follow sign for "95 south and Rt. 128 Burlington and Gloucester"; enter onto Rt. 95; continue south on 95/Rt. 1.
4.0	Cross over Rt. 128; continue south.
4.6	Exit on Rt. 129 east at sign "129 Lynnfield/Lynn."
4.9	Left turn at stoplight onto Rt. 129 east.
5.5	Enter rotary and bear right; follow Rt. 129.

8.8 Bear left on Rt. 129 at sign for Marblehead/Swampscott

9.2 Left (east) on Rt. 129.

9.8 Right on Rt. 129

9.9 Bear right on 129

11.3 Cross Rt. 1A

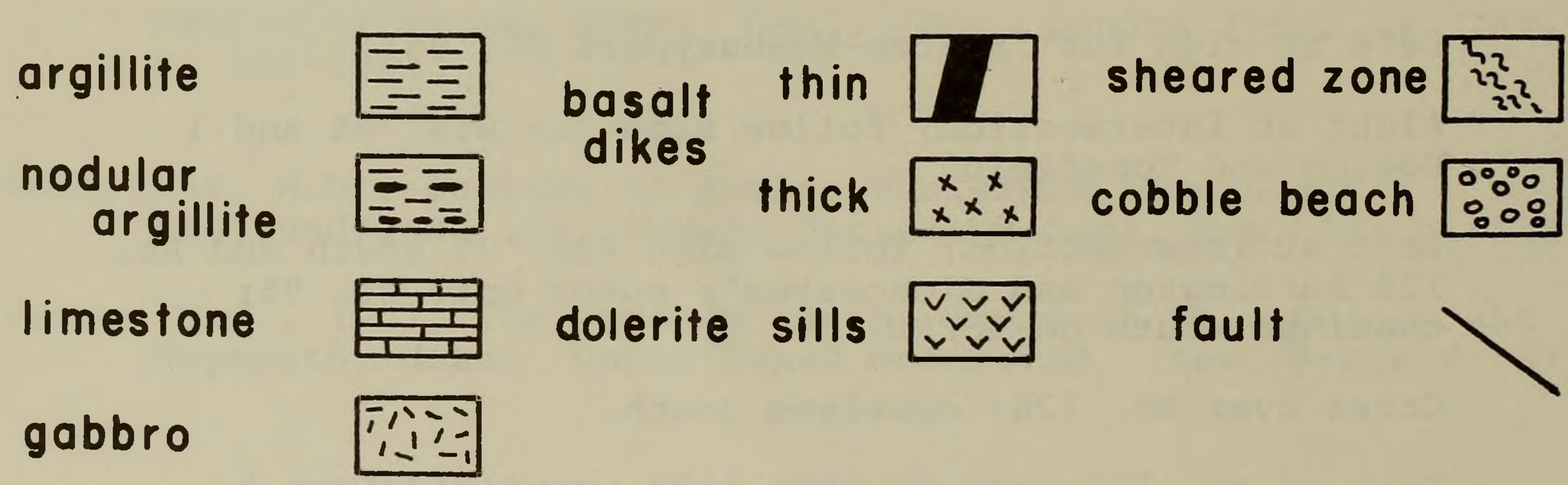
11.5 Right (south) on Lynn Shore Drive

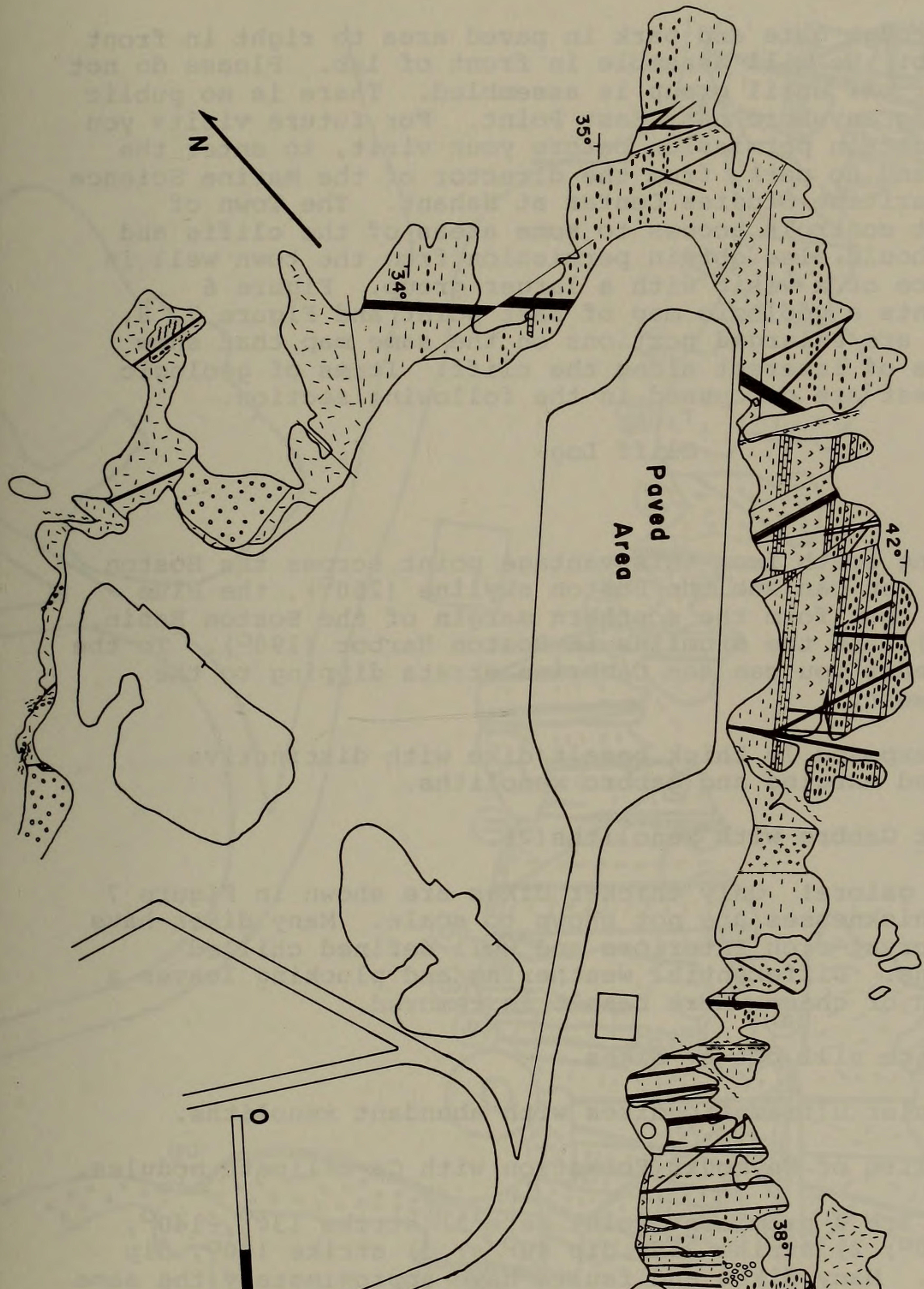
12.5 Enter rotary; go about 180° around rotary and bear right onto Nahant Rd. (causeway); continue on Nahant Rd. past Little Nahant through town of Nahant.

16.1 Bear left on Nahant Rd.

16.3 Bear left to gate at entrance to Northeastern University's Marine Science and Maritime Studies Center and Edwards Laboratory.

Figure 6
Geologic map of East Point, Nahant (on following page). Thin dikes not shown at true thickness. Rectangular or circular areas represent gun emplacements or pill boxes.




N
35°
34°
Paved Area
42°
38°
0
100m

16.35 Go through gate and park in paved area to right in front of lab. We will assemble in front of lab. Please do not wander off until group is assembled. There is no public parking anywhere near East Point. For future visits you must obtain permission before your visit, to enter the gate and to park, from the director of the Marine Science and Maritime Studies Center at Nahant. The Town of Nahant controls access to some areas of the cliffs and you should also obtain permission from the town well in advance of a visit with a larger group. Figure 6 presents a geologic map of East point and Figure 7, 8, and 9 are enlarged portions on the same map that show points of interest along the cliff. Items of geologic interest are discussed in the following section.

Cliff Log

Station

1 Looking south from this vantage point across the Boston Basin you can see the Boston skyline (250°), the Blue Hills that form the southern margin of the Boston Basin, (220°), and the drumlins in Boston Harbor (190°). To the northeast you can see Cambrian strata dipping to the northwest.

2 Well exposed 1m thick basalt dike with distinctive chilled margins and gabbro xenoliths.

3 Nahant Gabbro with xenoliths(?).

4 Dikes galore! Only thicker dikes are shown in Figure 7 and thicknesses are not shown to scale. Many dikes have phenocryst-rich interiors and well defined chilled margins. Differential weathering and plucking leaves a trench or chasm where basalt is removed.

5 Dolerite sill cut by dikes.

6 Irregular ultramafic dikes with abundant xenoliths.

7 Argillite of Weymouth Formation with Ca-silicate nodules.

8 There are 3 prominent joint sets 1) strike 130° -140°, dip 90°; 2) strike 235°,dip 40° s; 3) strike 100°, dip 55° S. Many dikes and faults have approximately the same orientation as joint sets 1 and 3.

9 Highly silicified and metamorphosed limestone. Fossils in poor condition.

10 Nahant Gabbro. Kaye (1965) discusses several unusual features of the gabbro.

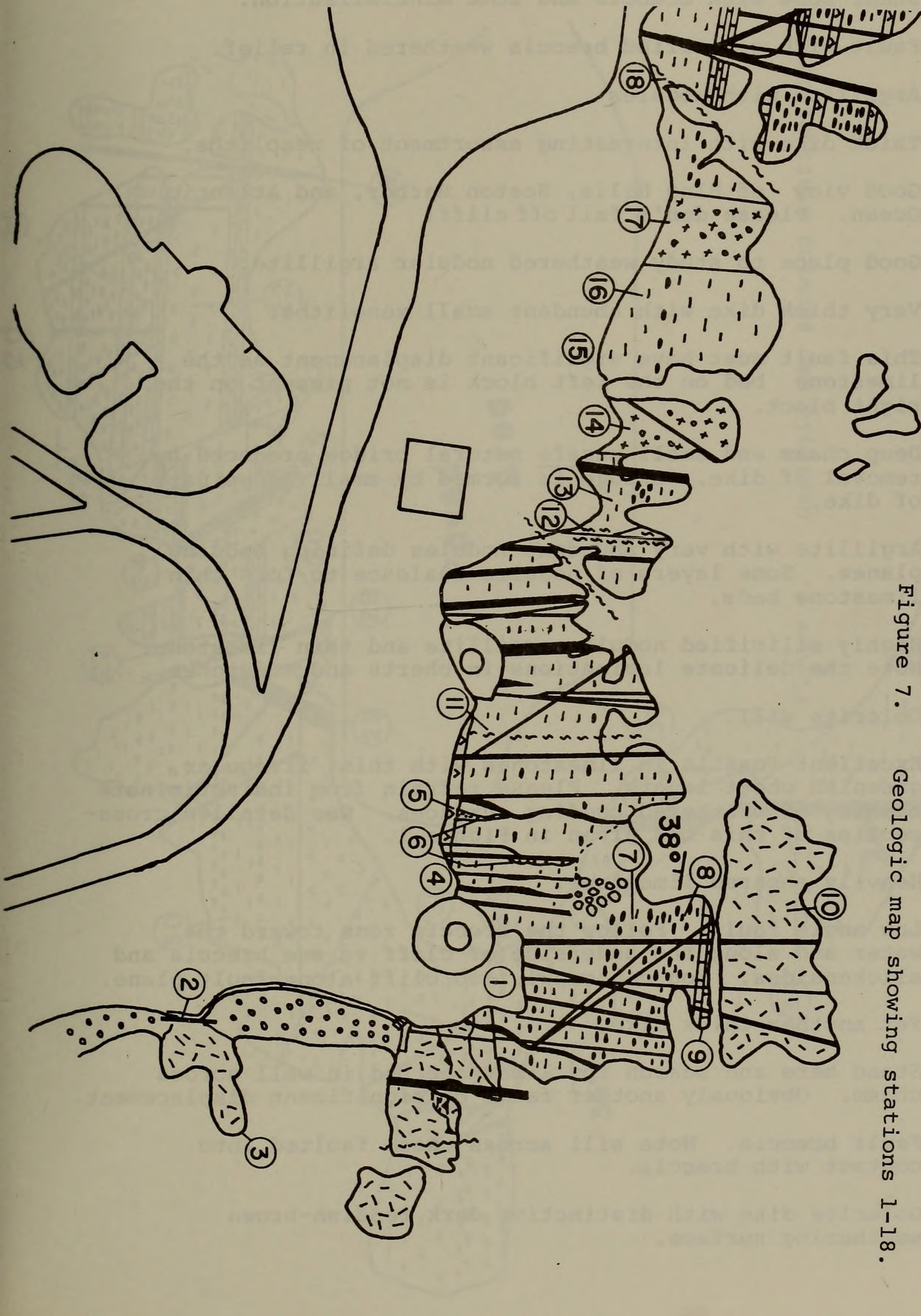


Figure 7. Geologic map showing stations 1-18.

11 Shear zone with breccia and some mineralization.

12 Fault with silicified breccia weathered in relief.

13 Argillite with nodules.

14 Thick dike with interesting assortment of xenoliths.

15 Good view of Blue Hills, Boston Harbor, and Atlantic Ocean. Please don't fall off cliff!

16 Good place to study weathered nodular argillite.

17 Very thick dike with abundant small xenoliths.

18 This fault must have significant displacement as the limestone bed on the left block is not present on the right block.

19 Deep chasm and small unsafe natural bridge produced by removal of dike. Bridge is formed by small wedged part of dike.

20 Argillite with very abundant nodules defining bedding planes. Some layers of nodules coalesce to form thin limestone beds.

21 Highly silicified nodular argillite and thin limestone. Note the delicate laminations in cherts and mudstones.

22 Dolerite sill.

23 Excellent fossils in limestones with thin, irregular, greenish chert layers. Please refrain from indiscriminate bashing of weathered bedding surfaces. See detailed cross-section of this bed given in Figure 1.

24 Heavily sheared limestone.

25 Low angle fault. Follow the breccia zone toward the water and along the underside of cliff to see breccia and slickensides. You can crawl into cliff along fault plane.

26 Yet another thick dike.

27 Stand here and search for limestone bed in wall across chasm. Obviously another fault of significant displacement.

28 Fault breccia. Note sill across chasm faulted into contact with breccia.

29 Dolerite dike with distinctive dark reddish-brown weathering surface.

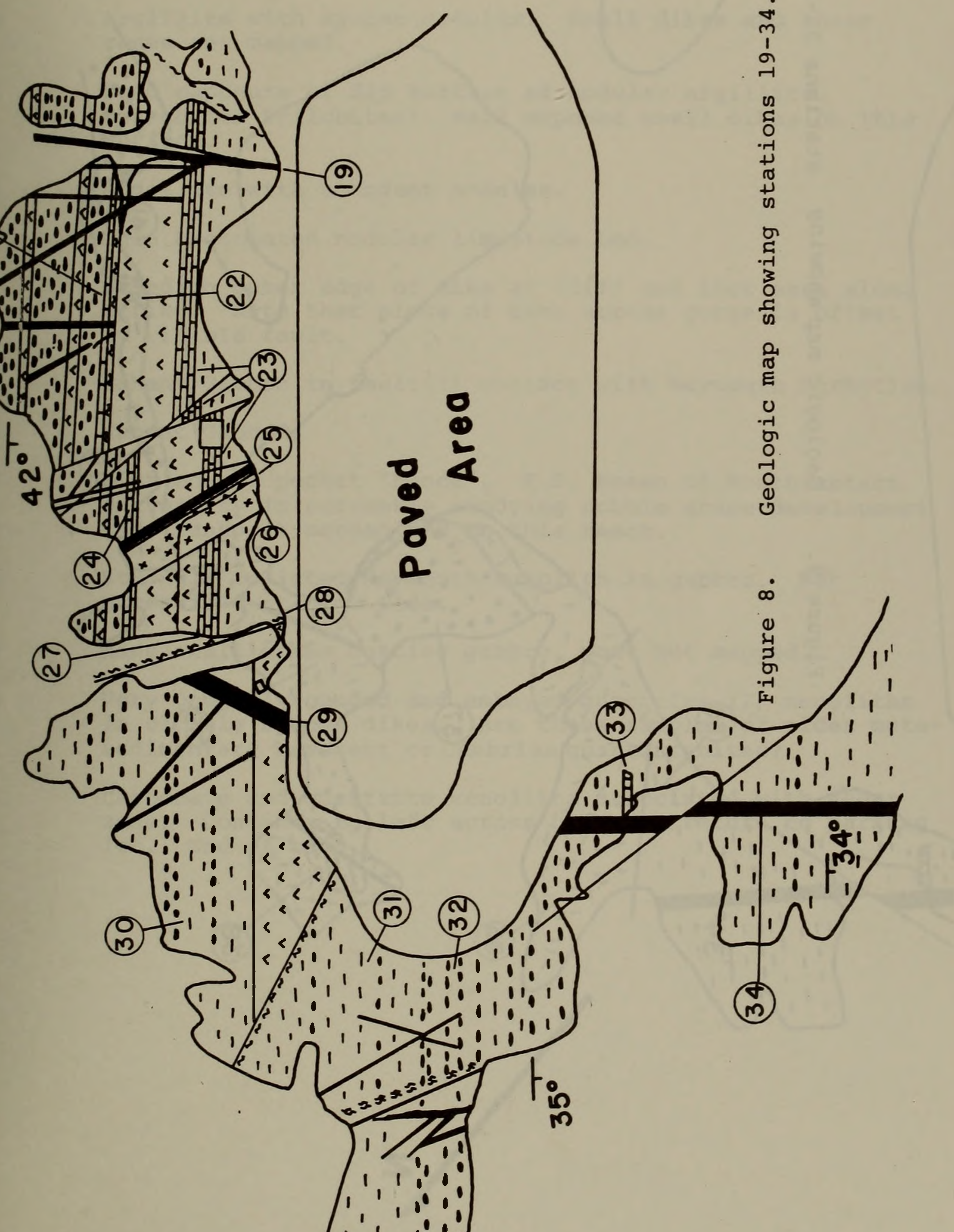


Figure 8. Geologic map showing stations 19-34.

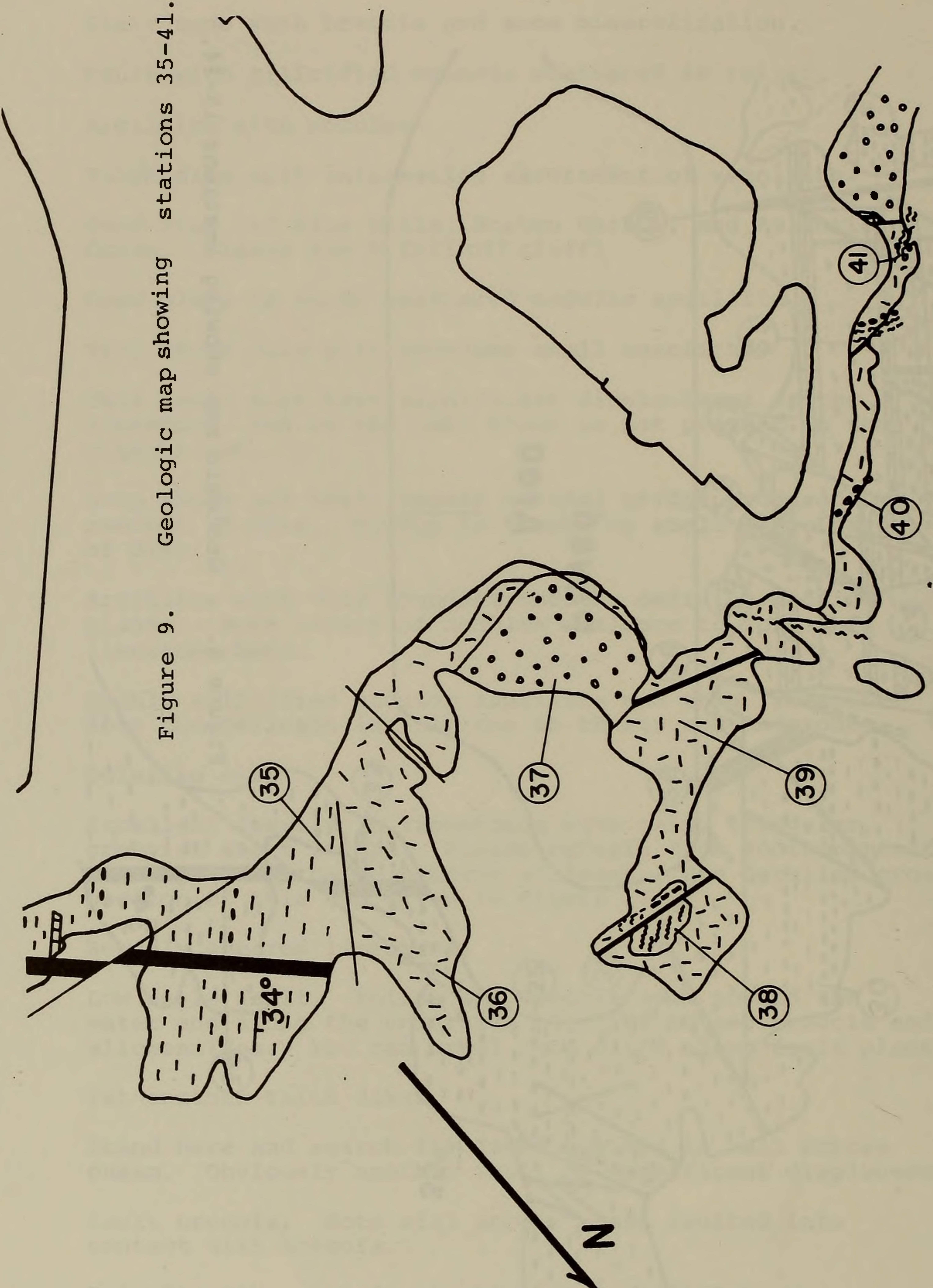


Figure 9. Geologic map showing stations 35-41.

30 Argillite with sparse nodules. Small dikes and shear zones not mapped.

31 Good exposure of dip surface of nodular argillite. Search for trilobites! Well exposed small dikes on this surface.

32 Argillite with abundant nodules.

33 Thin brecciated nodular limestone bed.

34 Stand on outer edge of dike at cliff and look east along strike. Note that piece of dike across gorge is offset by visible fault.

35 Nahant Gabbro in fault(?) contact with Weymouth Formation.

36 Nahant Gabbro.

37 High energy pocket "beach". P.S. Rosen of Northeastern University is currently studying cobble shape development and transport mechanisms on this beach.

38 Strongly foliated Weymouth xenolith in gabbro. Not accessible at high tide.

39 Many small dikes cutting gabbro, most not mapped.

40 Very unusual rounded and embayed quartzite (?) xenoliths in closely spaced dikes. Are these samples of older meta-sedimentary basement or Cambrian quartzarenites?

41 Carbonate and quartzite xenoliths associated with shear zone. Continue to left across beach to return to parking lot. End of trip.